

REMARKS

In view of the above amendments and following remarks, reconsideration of the rejections contained in the Office Action of June 18, 2007 is respectfully requested.

The Examiner's Position

The Examiner again rejected claims 1, 17-22 and 26 as being unpatentable over Tausig et al., U.S. Patent 6,311,759 (Tausig) in view of Kemnitz, U.S. Patent 5,778,533 (Kemnitz). The Examiner alleges that Tausig establishes that it is old to employ stainless steel employing most of the elements of claim 18 in similar percentages by weight, and that it is within the general skill of a worker in the art to select a known material on the basis of its suitability for the intended use as a matter of obvious design choice, citing *In re Leshin*, 125 USPQ 416. Kemnitz is cited by the Examiner to show one-piece steel piston formed by conventional forging.

In the Examiner's response to Applicant's arguments, the Examiner again takes the position that the selection of a known material is obvious and that the Tausig reference contemplates the use of the material in question. The Examiner further indicates that the Examiner is not convinced that thixoforging could not be adapted to the use of a known material such as steel. The previously cited reference to Winter et al., U.S. Patent 4,457,355, is also mentioned for the proposition of several materials possible for a thixoforging process.

The Tausig Reference

Tausig is employed for the proposition of thixoforming operations in general. The Examiner particularly points to examples of steel as found in Table 1. Tausig, it is noted, also directs its process toward the example of clutch hubs. The reference never discusses the possibility of or the advantages of making steel piston by a thixoforging process.

Table 1 of Tausig does recite three different steels for use in the invention of Tausig. However, Tausig never in fact discusses or describes in detail how such steels could be used. The series of experimental tests described beginning with the Detailed Description of the Invention in column 6 of Tausig is directed toward an aluminum alloy. None of the bibliographical references

that are found at the end of the Tausig specification, in column 11, appear to have any clear reference to steel. Reference 4 is specifically directed toward non-ferrous alloys.

Tausig further considers it as absolutely necessary to perform a first heating of the metal at or above the liquidus temperature before thixoforming the part. This prerequisite is not present with the present invention, and thus results in a significant advantage. This was thoroughly discussed in the prior response, which is hereby incorporated by reference in its entirety.

Because of the heating at or above the liquidus temperature in Tausig, the thixoforming is in fact closer to a rheocasting process than to thixoforging as used in the present invention.

Amendment to Claim 1

By the above amendments, independent claim 1 has been amended to recite that the steel part is cast in one piece so as to be in a first state. The subsequent heating of the billet takes place with the billet in that first state. Further, a subsequent heating of the billet is carried out without carrying out a separate operation of globulization of separated primary structure. This amendment is supported by the discussion in the first complete paragraph on page 5 of the original specification.

As discussed above, Tausig requires a second step, after obtaining material by conventional means such as casting in roll bars or billets. In that second step, a slug is remelted to bring it to a liquid state. Its temperature is reduced down to a temperature between the liquidus temperature and the liquidus temperature plus 10°C. It is cast at this temperature until complete solidification. The second step is part of the basis of the Tausig invention, and it is what gives the feedstock a globular structure that is helpful in the subsequent steps of Tausig. The second step of Tausig is not present and not required in the present invention, and this is now explicitly set forth in independent claim 1. For this reason alone, independent claim 1 distinguishes over Tausig.

Amendment to Claim 18

Claim 18 has been amended so as to be in independent form. The composition of a steel piston as recited in claim 18 is not present in Tausig or any of the other references cited by the

Examiner. For example, looking at Table 1 of Tausig, an H13 tool steel has too much Cr and V. The 304 and 316 stainless steels have far too much Cr and Ni, and not enough C.

In the Office Action, the Examiner took the position that it is within the general skill of a worker in the art to select a known material on the basis of its suitability for the intended use as a matter of obvious design choice. However, in thixoforging the nature of the material is not a matter of obvious design choice. The nature of the material is important to having a wide solidification range, which is the gap between the solidus and liquidus temperatures. This is discussed at lines 13-15 of the specification.

The Examiner's position that a specifically recited material is within the general skill of a worker in the art is respectfully traversed. This is not a matter of an "obvious design choice." The Examiner's citation of *In re Leshin* is not pertinent. In the case of *In re Leshin*, Applicant had conceded that the claimed molded plastic materials were well known, and simply argued that Applicant had to select them for a particular purpose. That is not the situation with the present invention. With the present invention, the particular material has been specifically arrived at for the purpose of thixoforging of a steel piston. There is no evidence or admission that the material is well known.

Independent Claim 26 Clearly Distinguishes Over Tausig

Claim 26 recites casting and cooling a steel material, heating the steel material so as to bring the steel material to an intermediate temperature between its solidus temperature and its liquidus temperature, wherein at least one of the casting, the cooling and the subsequent heating comprises obtaining a globular primary structure of the steel material. This is neither disclosed nor suggested by Tausig.

As explained in the prior response and as further discussed above, in Tausig there is an additional step required to obtain the globular primary structure. This step is not one of casting and cooling the steel material or heating the steel material to bring it to the intermediate temperature between its solidus temperature and its liquidus temperature. Rather, the step of Tausig involves remelting the slug to bring the slug up to a liquid state, after which its temperature is reduced down

to a temperature between the liquidus temperature and the liquidus temperature plus 10°C. It is then cast until complete solidification. This step is not required in the present invention, and it is in fact this step that gives the feedstock a globular structure that is helpful in the subsequent steps of Tausig. Thus, claim 26 clearly defines over Tausig for this reason.

The Examiner argues that this not true and that the casting process entails heating the material to a temperature hot enough to be cast. The Examiner goes on to discuss that Tausig teaches heating the material so that it is cast at a temperature in a range of the liquidus temperature to about 5°C above the liquidus temperature. This appears to be what obtains the globules as a separate step. In other words, it does not appear that the Examiner is in fact contradicting the analysis of the prior response.

Thus, it seems clear that claim 26 distinguishes over Tausig, and indication of such is respectfully requested.

Kemnitz

Kemnitz describes a process for making a single-part piston. However, the process that is described in Kemnitz is classic forging, followed by machining. It is clear to one of ordinary skill in the art that this forging is performed while the metal is in a completely solid state, and thus at a temperature that is lower, indeed by far lower, than the solidus temperature of the alloy. This is well known in the art and in contradistinction with the present invention in which the forging step is thixoforging and is performed at a temperature that is between the solidus and the liquidus temperatures of the alloy.

The inventive teaching of Kemnitz is that the conventional forged piston has a closed cooling duct. The duct is made by machining of the forged piston. By contrast, with the present invention, it is explicitly stated that the thixoforged piston has no cooling channels necessary. Note the fifth paragraph of page 9, and page 9 in general.

Kemnitz further discusses that the piston can be made of steel. This is one of a number of possible materials mentioned.

By contrast, with the present invention, only metals that are able to be readily thixoforged could be used, which is not the case for any kind of steel. Such considerations render it insufficient for a person of ordinary skill in the art to arrive at the present invention even if Kemnitz is considered together with Tausig. There is no disclosure of a material suitable for thixoforging a steel piston from either document.

Winter

While not cited specifically, the Examiner also does raise the patent to Winter. This document describes a device for obtaining and treating a metal in a thixotropic state, i.e. a semisolid slurry by electromagnetic stirring. An electromagnetic field creates a stirring force within the slurry.

Winter in fact describes a mold, on a repeated basis, suitable for forming such a thixotropic slurry. This allows the postponement of metal solidification. Winter clearly does not deal with thixoforging but explicitly deals with rheocasting. This process, as described in column 4, lines 37-41, consists in forming, from a liquid alloy, for a combination of heating and electromagnetic stirring, a thixotropic semi-solid slurry that will either be used in the form of a solid billet after it has been cooled to ambient temperature, or will be directly molded by die casting. The goal is to obtain a thixotropic slurry where the dendrites formed during solidification are “degenerated.”

Rheocasting is thus quite different from thixoforging. In rheocasting, the material is initially 100% in the liquid state, and its temperature is decreased so as to set it between the liquidus and solidus of the alloy in order to work on it in a mushy state. By contrast, for thixoforging, the process starts with a 100% solid material that is heated to the temperature at which it becomes partially liquid. This is distinct from rheocasting.

There is also no discussion in Winter of a process for making pistons or other precision parts. The only specific examples deal with low melting point aluminum alloys in Winter. This tends to indicate that Winter was directed to treating aluminum alloys having low melting points, in contrast to present invention, which is directed to the manufacture of steel pistons.

Additional Considerations

Accompanying the present response as Attachment A are chapters 5-7 of "Applications," a document of Applicant Ascometal. The document confirms that the thixoforging process is preferably performed on steel with a carbon content higher than 0.35%. A reduced solidus temperature and a wide interval between the solidus and liquidus are advantageous for thixoforging. Further, the type of steels referred to as "low thixoforging temperature" (LLT steels) was developed by Ascometal, the advantages of which can be seen from the figures on pages 6 and 7.

While Attachment A does not explicitly discuss the composition of the steels, this is discussed in Attachment B "Thixoforming of Steels and Industrial Applications", published in 2007. That is, the content of this document confirms the contents of Attachment A and the performance and advantages of thixoforging for producing low weight and near-net shape parts.

It is also noted that in prior art document such DE 101 10 769, EP 080786 and US 4,694,881, the discussion tends to dissuade one of ordinary skill in the art from using thixoforging.

The general tenor of these documents is that the Examiner's basic position that it is obvious to one of ordinary skill in the art to make a steel piston by thixoforging according to each of claims 1, 18 and 26 is not supported by a full consideration of all of the evidence.

Conclusion

In consideration of all of the factors and all of the evidence of record, it cannot be concluded that independent claims 1, 18 and 26 are obvious to one of ordinary skill in the art. The reasons have been clearly set forth above, and the Examiner's indication of the allowance of each of these claims, as well as the claims which depend therefrom, is respectfully requested.

In view of the above amendments and remarks, it is submitted that the present application is now in condition for allowance, and the Examiner is requested to pass the case to issue. If the Examiner should have any comments or suggestions to help speed the prosecution of this application, the Examiner is requested to contact Applicant's undersigned representative.

Respectfully submitted,

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ATTACHMENT A

APPLICATIONS

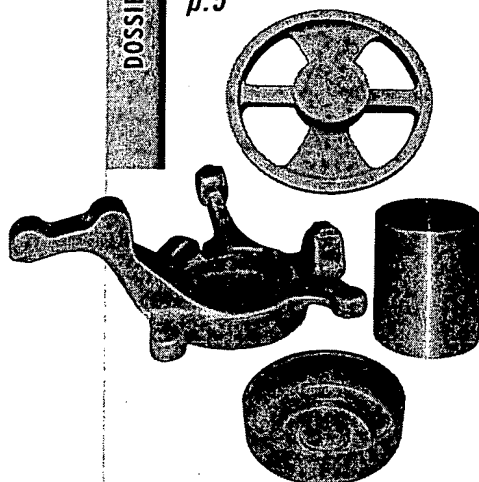
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ASCOMETAL

12 / 2005

DOSSIER

**THYXOFORGING:
AN OPPORTUNITY FOR
THE FORGING INDUSTRY**
p.5



**ESTAMFOR:
THE STRENGTH OF
A STRATEGIC VISION**
p.3

CALLING ON...



PROFILE

**RTD:
RESOLUTE, TECHNICAL
AND DYNAMIC
PERSONNEL**
p.8



SPOTLIGHT ON

**2005 TRADE SHOW
SPECIAL**
p.10



LUCCHINIGROUP

Jean-Paul MOROVAL
Chairman of the Board

Editorial

SPOTLIGHT ON

PROFILE

DOSSIER

CALLING ON...

Yet another extraordinary year!

Since 2004, the iron and steel industry and its customers have been confronted with a situation that changes every quarter. As from 2004, the cost of raw materials and energy increased to a hitherto unknown level. 2005 saw rising and falling fluctuations in the price of steel scrap and ferro-alloys, while the cost of energy (oil, gas and electricity) continued to rise dramatically. At the same time, business trends, which had been very positive over the past 12 months, flattened out somewhat at the end of 2005. Throughout the world, the industrial sector has had to develop an ingenious approach to manage this instability as effectively as possible. What does 2006 hold in store? While it is unlikely to be stable, it is clear that the recent events have taught companies to navigate more successfully through uncharted waters.

ASCOMETAL in 2005 and 2006?

ASCOMETAL has also had to adapt to the new economic state of affairs. Occasionally, the introduction of new production management tools has reduced our delivery performance and, unfortunately, new methods have not always been mastered as quickly as anticipated.

Like all other companies in the industrial world, we are continuing to work on axes of themes for improvement such as Product Quality or Service and Costs, without ever neglecting the time and energy required for the development of new products. In an increasingly globalised market, they are key to the common success of ASCOMETAL and its customers. Even greater emphasis will be placed on these areas of improvement in 2006.

A Challenge for Every Day.

SEVERSTAL, the LUCCHINI group's reference stock shareholder

In 2005, the Russian SEVERSTAL group became the majority shareholder of the LUCCHINI group. ASCOMETAL is now part of a group with a geographically wide industrial base (USA, western and eastern Europe) and an extended product range (flat and long steels).

ASCOMETAL's challenges

We are faced with a large number of challenges, both internally and on the market, and our customers contribute by helping us consider new technical horizons to push back the limits of special long steels. While some paths do not always lead to success, the acquired knowledge is real and is used for new projects: overall, the situation is clearly positive and we partially have you to thank for this.

Taking advantage of the publishing date for this latest issue of ASCOMETAL APPLICATIONS, in the name of all those working for ASCOMETAL, I would like to present you with our best wishes for professional and personal success and I am convinced that together we will be looking at a positive balance for 2006 on next year's December 31st.

ESTAMFOR: THE STRENGTH OF A STRATEGIC VISION

The approach taken by ESTAMFOR has been to establish itself as a leader in a few carefully selected strategic product ranges. This approach of developing markets has resulted in renewed profits.

"The FARINIA group is an ultra-light structure of four companies, in which each subsidiary has a maximum level of autonomy" explains Bruno QUEVAL, ESTAMFOR Managing Director. "This is what attracted me when I took over the management of ESTAMFOR in 2001. The company was unprofitable since 1992 and we decided to focus on a few strategic products by eliminating non-profitable parts and activities that did not fall within our competences."

In 2002, ESTAMFOR took over ELECTROFORGE, which specialised in electroforging. This enabled the

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The French group FARINIA acquired ESTAMFOR in 1999. FARINIA is organised around two sectors: smelting (FMGC in France and LUITPOLDHÜTTE in Germany) and forging, with ESTAMFOR, its ELECTROFORGE subsidiary and BDI, specialised in electroforging large parts.

company to make economies of scale by sharing structural costs and to profit from a real industrial synergy. Having been made a subsidiary, the machining activity was sold in 2003. In 2005, ESTAMFOR once again started making profits, with 5 % EBITDA. "We achieved this turnaround by choosing to concentrate on complex parts with a high added value for which we are not in competition with blacksmiths from Eastern European countries" explains Bruno QUEVAL. "To achieve this, we chose to invest in "brainpower", equipping ourselves with sophisticated design tools (Catia V5) and Forge 3 modelling tools, and by closely cooperating with our customers' technical departments. ESTAMFOR makes parts according to specifications provided by manufacturers and essentially delivers them to six major sectors: automobile, public works, handling, HGV, farming machinery and engine components. However, most of our activity is based on three strategic products: common rails (diesel direct-injection rails), steering gears for cars and forged tooth gears.

We are the only company in Europe to produce near net shape forged tooth gears: high precision parts, for which we have



1250 Kg hammer (BANNING)

developed a special forging process and which undergo 3D inspections. On leaving the production line, these gears just need a surfacing treatment. When compared with machined teeth, this process is much simpler and significantly improves the yield which, in turn, reduces the cost of the part. Essentially assembled for track transmissions, these gears are crucial parts for machinery that is often operated on very rough ground and in extreme conditions." The steering gears are standard >>

parts but ESTAMFOR has specialised in highly sophisticated models: mass-produced complex parts with rounded edges and different sections. "Quality requirements are very high for these safety parts that ensure the connection with the steering column. There are very few blacksmiths that can equal our performance of producing 5 to 6 million parts a year with zero defect. These parts are used to equip PSA (including the new 1007) and TOYOTA models. In the long term, we consider creating a new production unit in Eastern Europe which, in addition to our French plant, will bring us even closer to our customers and their markets."

While gears are important, there is no doubt that ESTAMFOR's current flagship product is the common rail. "The role of this direct-injection rail is to distribute pressure in

"ASCOMETAL provides us with 100 % of the steel we need for our strategic product, the common rail."

diesel vehicle injectors and cylinders. This part represents an important potential and the aim is to win over a large part of the European diesel car market by 2007 or 2010. The pressurised injection technology improves the energy efficiency rate and therefore reduces consumption and pollution. Once forged, the parts are painted and then delivered to a metal machinist who carries out the axial and longitudinal drilling and then assembles the injectors in a clean room." The pressure in these injector trains can



Bruno QUEVAL,
ESTAMFOR
Managing Director

Facts and figures

The FARINIA group

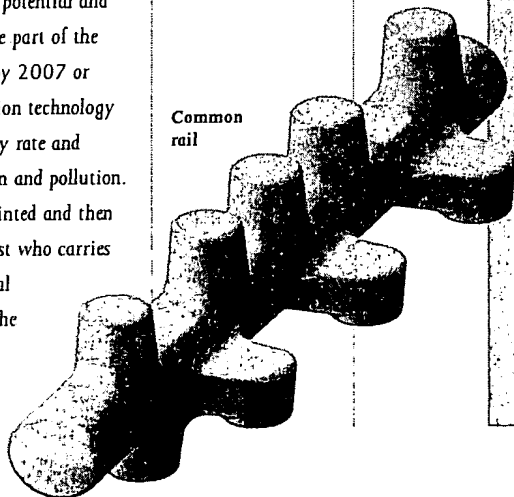
- Turnover: €163 million.
- Staff: 1,100.
- Growth forecast: an average of 12 % over five years.

ESTAMFOR (Hautes Rivieres, in the Ardennes)

- 2005 turnover: €25 million, 35 % of which from exports.
- Staff: 180.
- Equipment:
 - 1,250, 2,000 and 4,000 kg hammers,
 - one 10,000 kg hammer,
 - one 1,600 T maxipress,
 - one 1,600 T screw press,
 - two controlled cooling thermal treatment lines.
- Certification: ISO 9001, 2000 version and ISO/TS 16949, 2002 version.

reach 2,000 bars and, consequently, steel quality is a vital factor. "ASCOMETAL provides us with 100% of the steel we use for these parts, representing a third of our plant's total consumption. We are fully satisfied with both the quality of the product delivered by ASCOMETAL and the logistics. The METASAFE®/METASCO®/U 1000 grade is a micro-alloyed dispersoid without thermal treatment containing vanadium and lead that has been developed by ASCOMETAL. The Hagondange factory is the only plant in Europe to produce this steel, which has two major advantages: it offers an excellent mechanical pressure resistance, regardless of cooling speeds, and is easy to machine." ESTAMFOR now produces 8,000 common rails a day for the world's main car makers and many more common rails are currently being developed. "We are beginning to see the benefits of our industrial strategy, which consists in clearly identifying our know-how and in choosing products and markets that allow us to make full use of our skills, asserting our role as a major player in our specialised sectors", concludes Bruno QUEVAL. "Rather than a supplier, ASCOMETAL is a partner in which we have full confidence, and that is able to accompany us in our development." ■

Common
rail



THIXOFORGING STEEL: AN OPPORTUNITY FOR THE FORGING INDUSTRY

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Thixoforging, or the shaping of steel by forging when in a semi-solid state, is a hybrid process lying between forging and smelting. It consists of shaping a material whose structure, when associated with a heating cycle and temperature, gives it thixotropic properties. These properties are characterised by a reduced consistency due to the temperature as well as a reduced shear speed linked to the deformation caused by the shaping operation.

When used for steels, thixoforging presents interesting characteristics when compared with smelting or forging processes. The advantages of these semi-solid shaping processes are listed in tables 1 and 2.

(1) ADVANTAGES OF THIXOFORGING WHEN COMPARED WITH:

...forging	...smelting
Complex net shape geometric part	Greater mechanical characteristics
Low shaping effort	Lower shaping temperature
Major deformations in a single run	Better internal health

Types of steel for thixoforging

It is generally accepted that the thixoforging process can be carried out using steels with a carbon content superior to 0.35 %. The heating temperatures needed to obtain between 15 and 40 % of the liquid fraction in the billet prior to the shaping operation are between 1,300°C and 1,450°C depending on steel

grades. However, we have noted that to obtain a low liquid fraction variation, we often have to ensure a very precise billet heating temperature.

To improve the robustness of the steel thixoforging process, ASCOMETAL has worked on the development of new steels permitting:

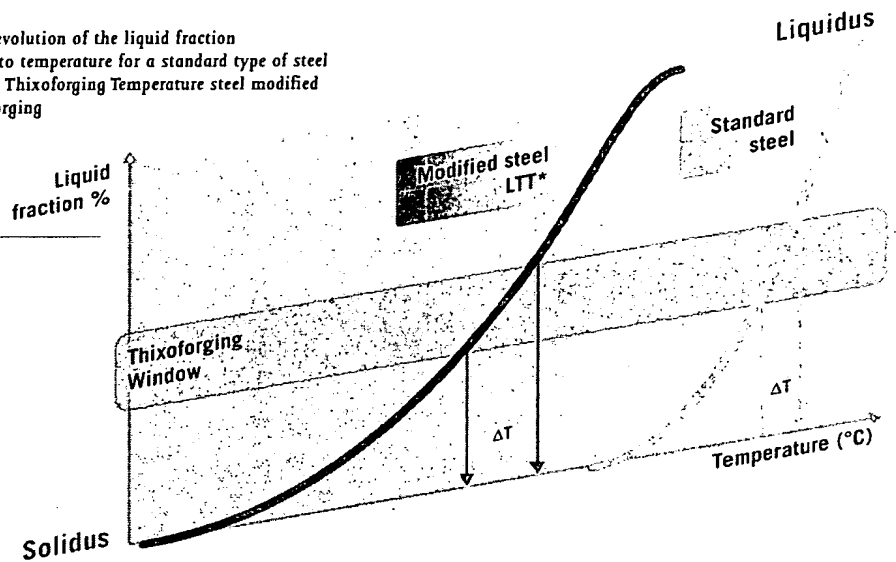
- a reduced solidus temperature,
- an increased interval between the solidus temperature and the liquidus temperature.

Figure 5 demonstrates the value of these new steels patented by ASCOMETAL, and that we designate as Low Thixoforging Temperature steels. Using LTT* steels, we can see that the tolerance on the billet heating temperature ($\Delta T^{\circ}\text{C}$), to obtain the right liquid fraction, is greater than for standard steels ($\Delta T^{\circ}\text{C}$). The robustness of the

(2) PARTICULAR THIXOFORGING REQUIREMENTS

Excellent geometrical and surface quality of billets
Good heating temperature precision
Adaptation of tools and equipment

Figure 5: evolution of the liquid fraction according to temperature for a standard type of steel and a Low Thixoforging Temperature steel modified for thixoforging



steel thixoforging process is considerably improved by the use of LTT* steel grades.

We will see that lowering the billet heating temperature, which is possible with LTT* steels, results in limiting the thermal constraints on tools during the

“Using the thixoforging process, internal shapes can be produced as net shapes: thin wall for the largest diameter, perfect angle geometry, and low surface roughness.”

semi-solid shaping process.

This new steel concept adapted to the thixoforging process can be applied to most steel grades used for mechanical applications.

Figure 6 presents the comparison, for various steel grades, of the liquid fraction evolution according to temperature between a standard type of steel and a LTT* steel.

*LTT: Low Thixoforging Temperature

Production of thixoforged parts

The examples shown in Figure 10 reveal the potential of the thixoforging process: large deformations, thin walls, considerable thickness variations and complex geometries. The part referenced (a) in Figure 10 presents numerous advantages, achieved through the steel thixoforging process, when compared to this same part produced by cast iron smelting. Using the thixoforging process, internal shapes can be produced as net shapes: thin wall for the largest diameter, perfect angle geometry, and low surface roughness.

The use of smelting to produce this part would require a large number of machining operations to obtain the same geometric precision and an identical surface condition.

For these types of parts, the metallurgical structure will

depend on the thixoforging conditions and the thermal transfer conditions between the shaped metal and the tools. In functional zones, the mechanical properties are those of the steel grade after controlled cooling and the endurance characteristics are between those of a forged steel part and those of a GS type smelted cast iron part.

Why is steel thixoforging an opportunity for the forging industry?

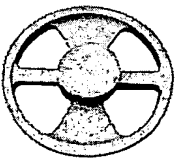
In today's world, the automobile industry's main concerns are to:

- reduce the weight of vehicles to reduce fuel consumption and, as a result, particle and gas emissions damaging to the environment,
- reduce the volume of active components: gearbox, engine, etc. to increasingly introduce components that increase passenger safety,
- reduce costs by:
 - using high performance

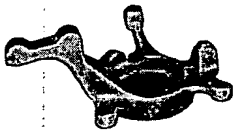
Figure 10:
thixoforged parts
(C38 steel)



(a)
ASCOMETAL
CREAS



(b) IFUM*



Steering knuckle

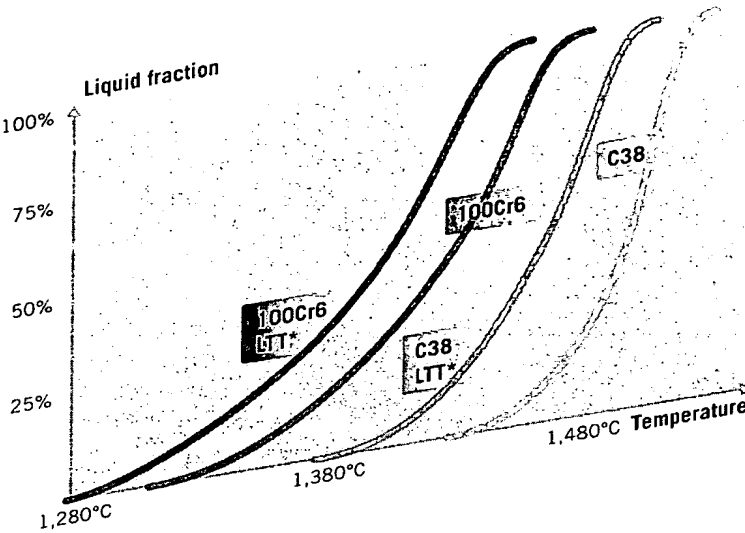


Figure 6: comparison between
standard steels and LTT* steels

processes to obtain net shape parts: the current rise in the price of materials requires that the gross charge per tonne between the "unfinished" and the "finished" parts be reduced,

- avoiding expensive assembly and mounting operations.

A current example of this type of part: a steering knuckle whose main component is formed from an aluminium alloy needs "added" parts to carry out its function. The use of a thixoforged steel part will, for example, allow to:

- reduce the number of parts and

of parts (steering knuckle for example) while providing equivalent or greater mechanical characteristics,

possibility of using industrial simulation codes such as Forge 2® or Forge 3® implemented with a semi-solid steel shaping module,

"...reduce the volume and the size of parts (steering knuckle for example) while providing equivalent or greater mechanical characteristics."

- obtain a similar weight to carry out the complete and complex function of a steering knuckle. Over the last few years, a large number of car parts have been lost by the forging industry to the benefit of cast iron or aluminium smelting processes, to meet the need for cost and weight reduction. Steel thixoforging could, in the near future, allow the forging industry to win back these contracts by offering parts with cost/weight and cost/performance ratios superior to those obtained using current processes and materials. The

should optimise the geometry of the parts: use of thin walls, ribs, etc., with the aim of obtaining an excellent weight (or volume) compromise given the use properties.

The availability of steels appropriate for thixoforging in the form of LTT* steel grades also guarantees this process will soon be industrialised. ■

"The robustness of the steel thixoforging process is considerably improved by the use of Low Thixoforging Temperature steel grades."

the gross charge per tonne necessary for their production,

- avoid assembly and mounting operations for the various parts,
- reduce the volume and the size

*IFUM : Institut
für Umformtechnik
und Umformmaschinen
der Universität

RTDs: RESOLUTE, TECHNICAL AND DYNAMIC

The RTDs are so involved in Customer/ASCOMETAL relations that regular readers of ASCOMETAL APPLICATIONS might ask themselves why it is necessary to devote two pages to ten people that they might think, often quite rightly, they already know. But whether you meet them on a regular basis or they work "behind the scenes", their activity is so wide-ranging and so fundamental to the quality of our ties with customers that we thought they deserved to be re-discovered.

Some of our RTDs come from the production sector and benefit from years of experience, while other younger ones are assisted by "seniors", but all ten of them have one vital point in common: a detailed understanding of

Viz

Located on the different sites, each team is run by a manager who relies on the engineers responsible for technical relations with customers.

A typical week:

- Site meetings to cover various technical aspects with the concerned departments.
- Supervision of test casts.
- Project meetings with CREAS.
- Factory audits for customers.
- Running a work group with a prime manufacturer.
- Customer visits.
- Preparing a presentation for a conference.



ASCOMETAL plant processes, an excellent awareness of customer applications and a well-founded appreciation of the downstream transformation of our steels. They carry out a dual function: providing customers with technical assistance and contributing to the development of new products. Whether they are involved in the Automobile, Bearing, Spring, Mechanical or Oil/Gas/Mines sectors, their job requires great versatility. Their strength lies in their capacity to communicate clearly and thus ensure that information is well-distributed (both to collect demands expressed or suggested by our customers and transmit ASCOMETAL proposals to customers). Their work takes them to the five continents and

this, by definition, requires that they master a foreign language. Reporting to the Central Marketing Manager and working closely with the contract teams in the sales department, the role of the RTD engineers has changed over the past few years. Beyond day-to-day activities (customer visits, site meetings, dispute/product quality interaction management, optimisation of production ranges, etc.), they also get involved in longer-term projects to anticipate the expectations of the various parties which constitute the industrial chain. As an interface between customers and the plant, backed by the sales network, RTD engineers need to fully grasp the needs expressed by customers to provide the best adapted answers.

PERSONNEL



They must also clearly understand the production processes to propose optimised solutions. Their missions range from the "simplest" (adjustment of temperature parameters in a customer process) to the most fundamental (change in metallurgical grade, checking steel making parameters, etc.), including all the measures that can help to simplify a customer's life (improved packaging methods or trucks loads, certificate formalities, etc.). Having to confront a wide range of situations and all types of problems, RTDs rapidly increase their experience and become a vital focal point for internal and external contacts: they have a clear understanding of the market and are aware of technological trends/directions (process,

"They also get involved in longer-term projects to anticipate the expectations of the various parties which constitute the industrial chain."

materials, etc.). With a total respect for professional secrecy and with an ethical code that has never failed over the years, RTDs accompany our customers in their developments.

The Research element is also very important as the RTDs make a considerable contribution to identifying new developments and setting up and monitoring projects. These projects must correspond to the objectives pursued with the customers within the scope of technical partnerships.

To allow the company to retain its leader position and its technological advance, in addition to CREAS, they keep an

eye on developments in the technical and commercial environment. On a day-to-day basis, pushed by our customers and occasionally retargeted by the production teams, it is also the RTDs who, by clearly introducing the "customer's voice" into the plant, help ASCOMETAL go even further in constantly improving Quality and proposing even more innovative solutions within an industrial and economic framework acceptable to all. They provide technical training for both ASCOMETAL personnel and occasionally customers and participate in preparing technical sales aid documents. In a nutshell, this key function within the company requires a technical profile, a well-founded metallurgical culture and excellent human relation skills. ■

Profile of an ASCOMETAL RTD

- Good listening and communication skills, inquisitive nature.
- Ability to work with a team.
- A dynamic approach.

2005 TRADE SHOW SPECIAL

During 2005, ASCOMETAL participated in two symposiums on thermal treatment and surface engineering.

Viz

The conferences taking place during these symposiums focused on topics concerning accomplishments and innovations achieved in partnership with customers and suppliers.



**A3TS, Reims
from June 15th to 17th, 2005**

Organised by A3TS, over 60 specialists in materials, thermal treatment, surface treatments, laboratory and inspection equipment, etc., were present as exhibitors. ASCOMETAL carried out several presentations

“With the METASCO® and SPLITASCO® brands ... ASCOMETAL ... has developed a new generation of forging steels...”

on subjects such as thixoforging (see p 5-7), the new generations of micro-alloyed forging steels, and the development of a new steel for PSA crankshafts in collaboration with FORGES DE COURCELLES and PSA.

The new generations of micro-alloyed forging steels: developments and prospects

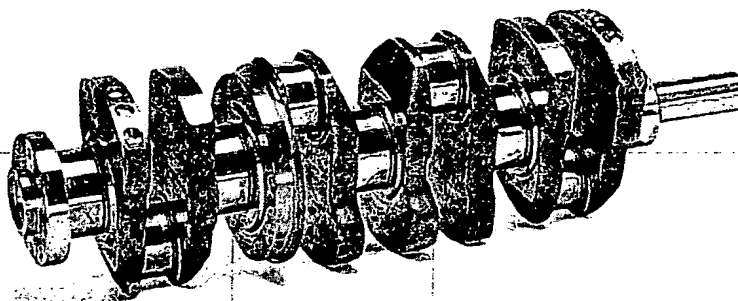
Micro-alloyed steels have now become essential for the

production of forged parts, to such an extent that over just a few years they moved from being a solution substituting for hardened and tempered steels to being an integral part of the types of steel made available to engineers.

With the METASCO® and SPLITASCO® brands, developed to meet increasingly demanding needs for reliability and increased service performance, ASCOMETAL has both increased the performance of existing solutions and developed a new generation of forging steels able to meet the requirements of the entire industrial chain in terms



A crankshaft



**AWT, Wiesbaden (Germany)
from October 5th to 7th, 2005**

This yearly symposium is always much appreciated by manufacturers (manufacturers of treatment furnaces, blacksmiths, automobile subcontractors, etc.). For many years now, ASCOMETAL has been invariably present at this event, both as exhibitor

of use properties (forging, machining, etc.) and service properties (fatigue resistance, etc.). The presentation specifically dealt with the innovations of the new generation of METASCO® and SPLITASCO® grades, particularly their high mechanical characteristics applicable to both forged parts and ready-to-use bars for machining and turning.

**The development of a new steel for
Psa crankshafts in collaboration with
FORGES DE COURCELLES and Psa**

This is a first in the world of forged steel car components, being able to provide a resistance superior to 1,000 MPa in the heat of the forge and thus meet the manufacturer's specifications:

- **Ensure the part's performance when under load: + 20 % compared to existing standards:**

This was checked using appropriate testing methods and validated on engine test beds.

- **Take the following process constraints into account:**

- *Forging:* working of raw material, without subsequent dipping or tempering treatment.

- *Machining:* machinability using the means available in the PSA PEUGEOT CITROËN plant.

- *Reinforcement:* by roller-burnishing.

- *Related treatment:* dipping after heating by induction of spans.

The PSA - ASCOMETAL and FORGES DE COURCELLES presentation dealt with the technico-economic result as well as the development approach, known as the "V cycle approach", adopted by the three partners and which is widely used by PSA PEUGEOT CITROËN.

This approach can be broken down into three main phases:

- *Engineering:* design of the product/process by PSA.

- *Production:* launching of the product, machining on existing PSA lines

- *Validation:* inspection of obtained characteristics and feedback where applicable.

Applied to the ASCOMETAL specialty, METASCO® MC, this approach will, in the next few months, result in a crankshaft for some of the highest performance engines in the PSA range.

"This is a first in the world of forged steel car components, being able to provide a resistance superior to 1,000 MPa in the heat of the forge."

and lecturer. In partnership with BISHOP, acting for BMB Steering Innovation GmbH (rack manufacturer), ASCOMETAL has developed the advantages of bainitic microstructures by illustrating the high performance level obtained on a steering rack.

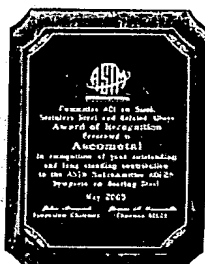
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ASTM 2005

 American Society for
Testing of Materials

This year, the 7th International Symposium on Bearing Steel Technologies took place in Reno (USA). On this

occasion, ASCOMETAL received an award for its constructive and efficient involvement with the entire bearing industry.



Properties of bainitic structures obtained through controlled cooling

Micro-alloyed steels having been obtained through cooling present a ferrite-pearlite or bainitic microstructure. Depending on the process set up by the customer and the part's functional specifications, one of these microstructures is chosen. Using physical metallurgy criteria, it would appear that in many cases, the bainitic structure provides a better compromise between the various installation and use properties. In addition, bainite's various morphologies, ranging from upper to lower bainite and granular bainite, allow a vast range of mechanical properties to be covered. These properties greatly depend on the various parameters comprising the microstructure, such as the precipitation of vanadium carbonitrides and the dimensions of the bainite laths.

Bainitic metallurgies have standard analytical bases, Mn, Cr, Mo, Si, B, V, etc., and present shaping properties similar to those of standard construction steels.

This type of microstructure is particularly well adapted to certain processes, such as semi-hot forging or partial heating, and full use is made

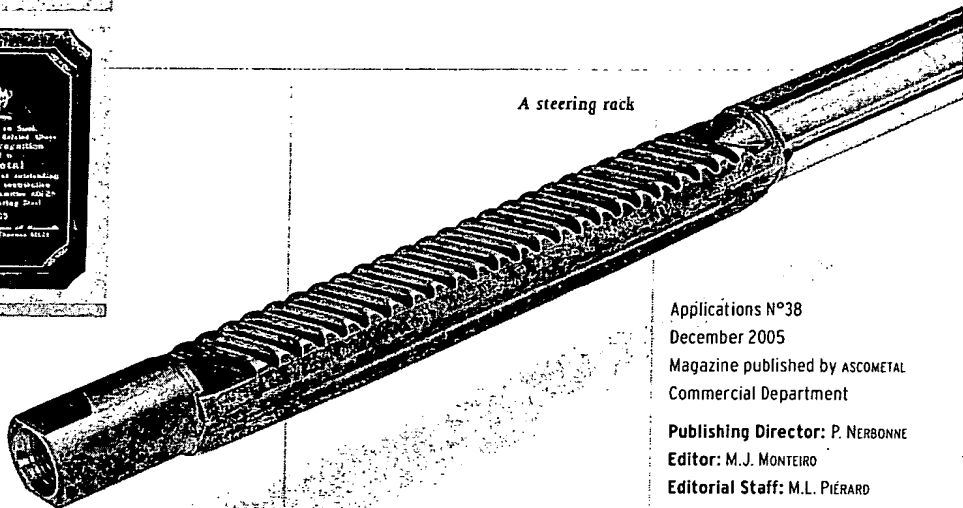
"In partnership with BISHOP, acting for BMB Steering Innovation GmbH (rack manufacturer), ASCOMETAL has developed the advantages of bainitic microstructures by illustrating the high performance level obtained on a steering rack."

A microstructure



of the structure's particular characteristics. In terms of machinability, comparisons between ferrite-pearlite and hardened and tempered steels of similar mechanical characteristics will be presented. ■

A steering rack



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LUCCHINIGROUP

ATTACHMENT B

Thixoforming of Steels and Industrial Applications

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Abstract. Thixoforming of steels becomes more and more investigated. Recent works show the economical potential of the process and lead to many industrial tests. In deed, compared to light metals, thixoformed steels open new markets and allow new designs of industrial parts taking into account, material and energy saving as well as industrial criteria such as parts quality and life.

The Thixosteel consortium is developing new tools either in modelling, material study, assessment, parts design, adequate tools and equipments. Recent results and actual state of the art is presented and discussed.

Keywords: Steel, Thixoforming, Industrial applications.

PACS: 81.05.-t

INTRODUCTION

The industrial implementation of new technologies depends mainly on the achievable cost savings by means of reducing e.g. the energy and material consumption, the final machining of the part as well as the final material behaviour. Therefore within the last years different near-net shape technologies were developed, e.g. finless precision forging technology and thixoforming of light metal alloys [1].

Respecting these facts the thixoforming technology of steel grades, which is not yet realized in industrial applications, seems to be a very promising technology for the future which merges the advantages of the forging technology regarding the improved material behaviour and the advantages of casting processes regarding the flexibility of the producible part geometry. Next to the following advantages for industrial applications by using the thixoforming process of steel grades can be expected:

- Shortening of production cycles by eliminating operations (forging steps, clipping, punching, final machining) and incorporating all remaining operations into a single line
- Reduction of cycle time, compared to casting, and thus a reduction of delivery time to customers
- Decreasing of the economic batch size by means of increasing flexibility

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In connection with the market situation the thixoforming of steel parts is interesting for those parts that are currently made of cast iron or aluminium alloys for the following reasons:

- Cast iron parts: are cheaper to produce than conventional forging parts, but machining after the forming step is necessary and mechanical characteristics are not as good. Thixoformed parts are expected to be designed with lower weight in combination with a given strength. Drawings of cast iron parts are very similar to those drawn for forging purposes, but the dimensions might be bigger because of the worse mechanical characteristics.

- Aluminium Parts: they could probably be replaced by smaller thixoformed parts because steel shows better specific mechanical characteristics.

ADAPTION AND RE-DESIGN OF THE PART FOR THE THIXOFORMING PROCESS

It is necessary to redraw and to resize the parts in order to fit the geometry to the better specific mechanical characteristics of thixoformed steel alloys.

It is, of course, necessary for the re-design to consider special features, such as bearing, centring, guiding and connecting functions.

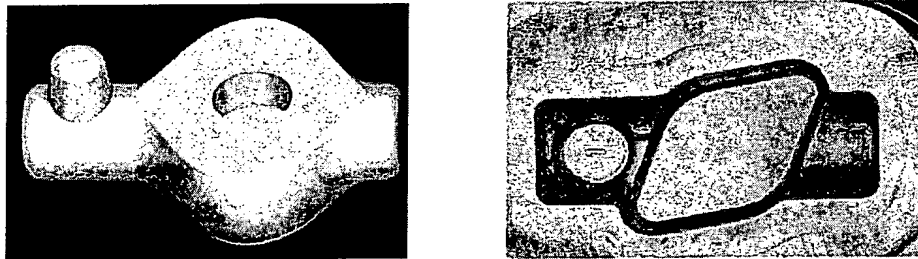


FIGURE 1. Re-designed SKL-Flange and the existing one produced by drop forging.



FIGURE 2. Re-designed brake calliper and the existing one produced in cast iron.

The re-design (Figure 1) of the existing SKL-flange and Front brake Caliper (Figure 2) was carried out with considering the following points:

Geometry: In order to obtain a laminar flow of material the number of sharp edges was kept as low as possible. Of course the connecting and functional dimensions were not modified in comparison with the original part.

Tool material: Regarding the tool material (ceramic or steel) the number of sharp edges had also to be reduced to a minimum and whenever possible rugged edges were replaced by smooth radii.

ADAPTATION AND MODIFICATION OF DIFFERENT STEEL GRADES

First tests on classical steels, e.g. carbon steels, show a narrow thixoforming window and thus do not allow a safe thixoforming process due to the important liquid fraction change in regarding small temperature change in one hand, and on the other hand, present a higher solidus temperature having a bad consequent on die life. Therefore, the adaptation of steel grades to thixoforming is a very challenging point.

Determination of casting conditions

Industrial continuous casting conditions were realized at ASCOMETAL–LUCCHINI-Group. For the different cast products the classical solidification zones are visible and are significantly different: columnar, equi-axial.

From samples taken out of the equiaxial zone of various cast products, we carried out tests of heating with a cycle adapted to obtaining a globular primary structure, we could not observe significant differences, between different studied cast conditions: dimensions of globular structures after heating with an adapted cycle and quick cooling to solidify the structure to be observed.

The structure analysis after heating the material to a temperature between the solidus and the liquidus lines puts in evidence that the segregation and micro-segregation are essential for obtaining "spherical" primary structures and so to improve the thixoforming deformation. This segregation also allows a more premature appearance of the liquid phase while widening the domain included between the solidus and the liquidus.

These developed steel grades are dedicated to improve the thixoforming operation without altering the mechanical properties of the realized samples. For all steel grades that are common in mechanical engineering with a carbon content included between 0,35 % and 1,2 % it is possible to realize industrially steel grades adapted to the thixoforming process.

Determination of rolling Conditions

From the various continuous cast and ingot elaborations studied, we carried out rolling operations to obtain different products with section directly usable for the thixoforming operations and this for some steel grades. The heating operations are carried out under conditions adapted to the thixoforming operations then the slug is cooled quickly to solidify its primary structure.

Adaptation and Production of different Steel Grades

Elaboration and hot rolling tests realized on some steel grades adapted or not to the thixoforming process allow describing the steel elaboration and the thixoforming operation. The process used to obtain the thixoforming steel bars is classical, first steel elaborated with continuous casting or ingots and hot rolled to obtain the good diameter, then, it is necessary to cut the bar by precision shearing or sawing for obtaining slugs with excellent geometrical quality and good dimensions for thixoforming process.

We have studied the possibility to increase the reliability of the thixoforming process and actually, we can propose steel grades adapted to thixoforming because solidus temperature is decreased and range between solidus and liquidus is increased.

With these adapted steel grades, it is possible for a same thixoforming window or the same liquid fraction to increase the temperature tolerance and to increase the reliability of the thixoforming process. These steels are patented by ASCOMETAL [2] and the denomination of these steels grades is "Low Thixoforming Temperature" (LTT steel grades). Figure 3 shows liquid fraction behaviour of a C38 steel grade compared to the adapted steel C38LTT.

These curves were obtained in laboratory conditions by DSC at low heating rate of 20°C/min [3].

In these conditions, the results are given in Table 1 for the steel grades 100Cr6, 100Cr6 LTT and C38, C38 LTT.

TABLE 1. Solidus and Liquidus temperatures of adapted steels and classical one.

Steel grade	Solidus temperature (°C)	Liquidus Temperature (°C)	ΔT
100Cr6	1315	1480	165
100Cr6LTT	1280	1460	180
C38	1430	1530	100
C38LTT	1380	1510	130

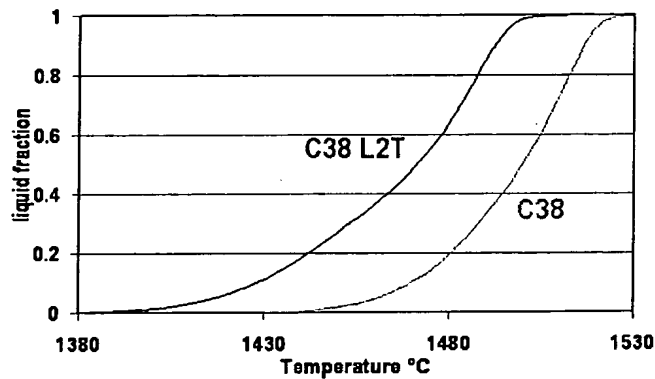


FIGURE 3. Comparison between C38 and C38 LTT steel. Liquid fraction = $f(\text{temperature})$ was obtained by Differential Scanning Calorimetry (DSC) at a heating rate of 20°C/min.

THIXOFORMING PROCESS

Afterwards, the high temperature obtained with the heating cycle permits to obtain in the slug a primary globular structure adapted for the thixoforming process.

The slug transfer between the heating zone and the press is critical and should be realized with adapted handling system that allows fast transfer. The last step is the slug deformation in semi-solid state to obtain near net shape or net shape parts with complex geometry.

This manufacturing line is equivalent to the hot forging fabrication line.

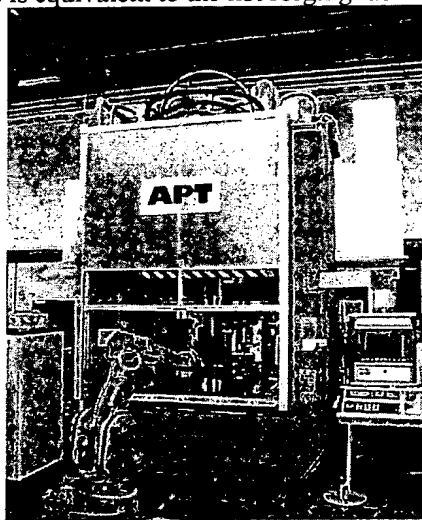


FIGURE 4. Typical Hydraulic press used at the thixoforming Unit of the University of Liège.

The heating cycle is very important to obtain the best thixoforming conditions. To obtain an ideal proportion of liquid phase in the slug, between 20 and 50%, it is necessary to adapt the heating conditions in order to have good proportion between liquid and solid fraction and the best homogeneity in the entire slug. The heating cycle must also be adapted for obtaining the primary globular structure at the thixoforming temperature.

In order to ensure a homogeneous steel flow at the semi-solid state, it is necessary to obtain in all points of the parts a high speed deformation [4], this could be achieved using for example hydraulic presses as depicted in figure 4.

CONCLUSION

To this day, our knowledge of thixoforming operations for steel alloys does not allow us to guarantee a total absence of micro - porosities in parts. The mechanical characteristics and fatigue properties of thixoforged steel parts are comparable to the mechanical characteristics and fatigue properties of forged steel parts [5].

The surface roughness of a thixoforged steel part is excellent and for some mechanical requirements (flexion, ...), this good surface roughness is an important advantage compared to the quality of surfaces obtained by foundry processes but equally by hot forging. The good ductility of the numerous steel grades is a good advantage compared with cast iron and aluminium alloys esp. for security parts.

In conclusion, thixoforming of steel grades is an outstanding and promising technology to realize an extremely flexible production, in order to achieve good material behaviour, to obtain near-net shape pieces with good surface quality and to improve the economic boundary conditions.

ACKNOWLEDGMENTS

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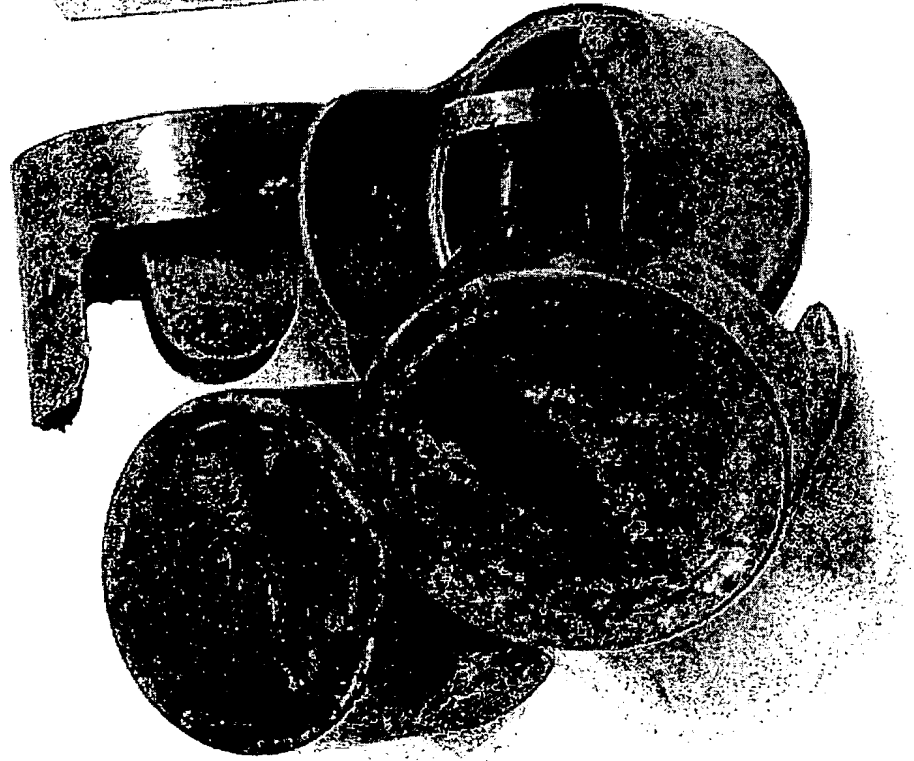
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ATTACHMENT C

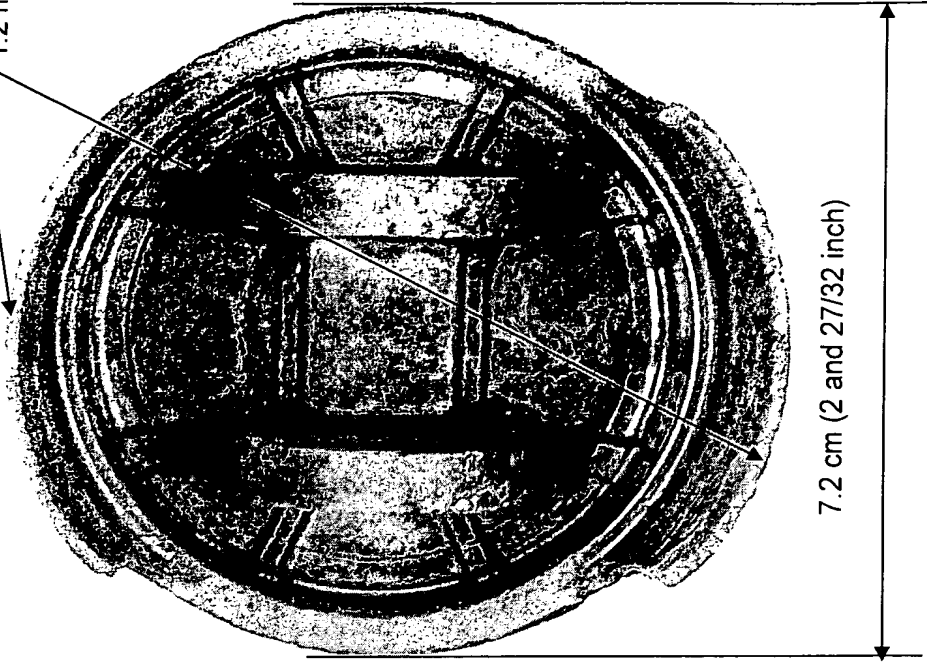
Steel as-thixoforged car pistons according to present application

General view



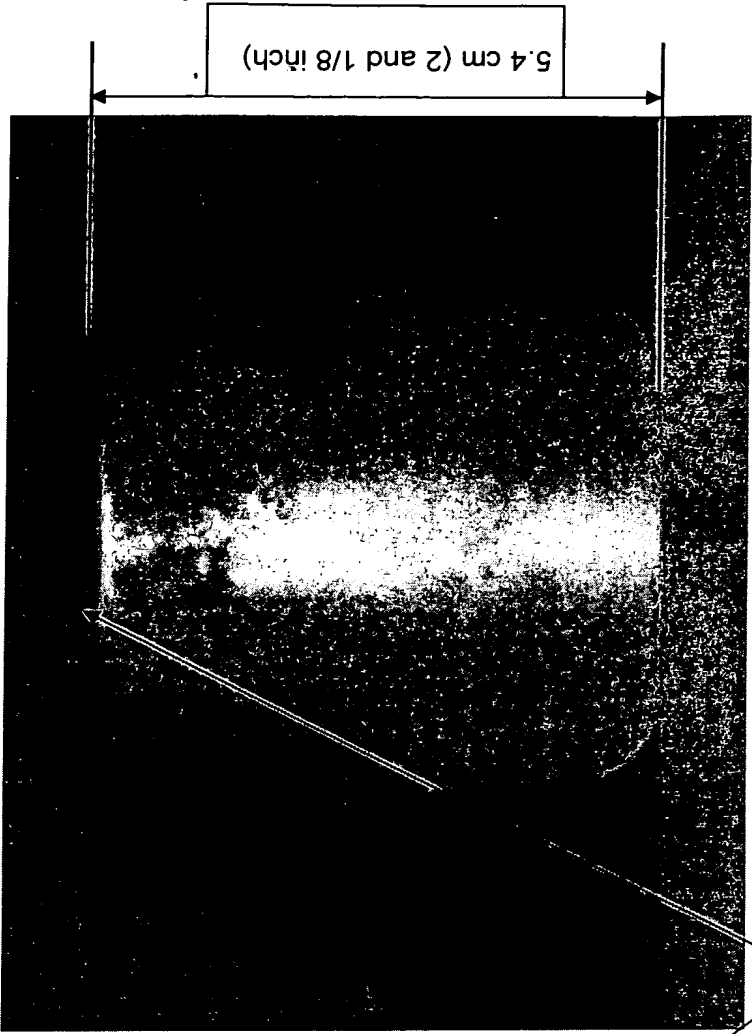
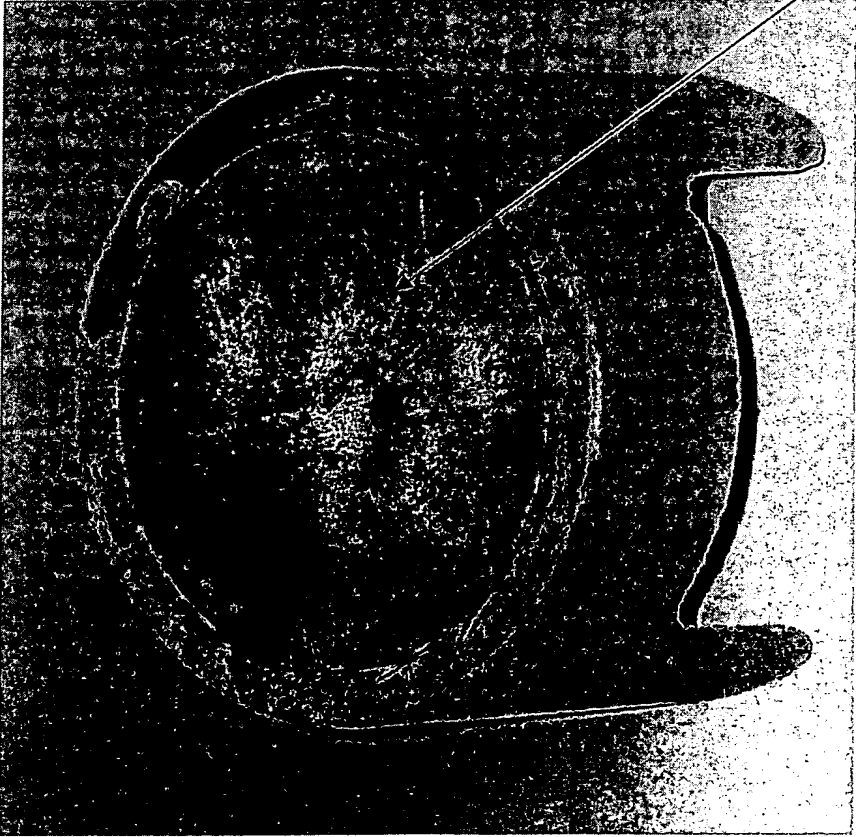
Internal view

Thinnest sections :
1.2 mm (3/64 inch)



Steel as-thixoforged car pistons according to present application

Vertical/external view



Piston Top